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Research Article

Synthesis of Integral Models of System Dynamics of an Acid-Base State (ABS) of Patients at Operative Measures

Kurapeev DI[1], Lushnov MS[1], Osipov VYu[2], Vodyaho AI[3] and Zhukova NA[2,4]*

[1]*Almazov National Medical Research Centre, St. Petersburg, Russia*

[2]*St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences, St. Petersburg, Russia*

[3]*St. Petersburg State Electrotechnical University, St. Petersburg, Russia*

[4]*ITMO University, St. Petersburg, Russia*

***Corresponding Author:** Zhukova NA, Almazov National Medical Research Centre, St. Petersburg and ITMO University, Russia.

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Abstract

In the paper the problem of synthesis of integral models of system dynamics of an acid-base state of patients at operative measures is discussed. Model synthesis is based on methods of complex analyses of the organism. According to these methods the key indicator that can characterize the state of the organism is consistency of the dynamics of changes of its parameters. To estimate such changes criteria functions and functionls are calculated. The results of experimental research are given.

Keywords: Models; Dynamics; Acid-Base

Introduction

Each biological organism represents a complex system. The research of a set of properties of these organisms resulted scientists and specialists in need to develop system approaches for the analysis and assessment of the changes happening in them.

Use of system approach provides consideration of a biological organism as a complete complex of the interconnected elements. For patients adaptive mechanisms can be observed in many functional systems: leukocytic, biochemical, electrolytic and others.

In the process of analysis of changes in a physiological system the coherence of internal interaction of its elements defining ability of an organism to self-organization and adaptation is of interest.

Main objective of studying of self-organizing systems is assessment of their functional state in general and management of them taking into account the external and internal influencing factors.

It provides definition of integrated indicators of a condition of organisms. Due to the large volume of observed clinical parameters and a big number of correlations between them automation of calculations of such indicators is necessary for operational assessment of a condition of organisms. For this purpose medical information systems (MIS) must have mechanisms for estimation of organism condition on basis of results of analysis. Now such opportunities are not always supported by MIS.

The existing MIS from the point of view of complexity of the realized functions can be classified into four classes: MIS for data acquisition, MIS with functions of statistical information processing, intelligent MIS with ability to work with knowledge. For realization of system approach in MIS in particular it is necessary to describe processes of synthesis of integrated models of dynamics of changes of conditions of an organism and the models and techniques corresponding to them.

In this article synthesis of models of an organism on the example of creation of models of the acid-base state of an organism based on using optimization methods and multivariate statistics is considered. The task to reach the level of artificial intelligence and the task of automated medical decision support systems development is not set here because it would involve considerably great efforts and costs. In this case it would be necessary to consider multidimensional comparison of the acid-base state of the parameters proposed for consideration with some integrated medical assessments, such as scores, patient state scales and medical verbal conclusions with appropriate text analysis.

Methods of the system analysis of conditions of biological systems

Many researchers offering various indicators were engaged in assessment of a functional condition of an organism: physiological, medical, single, complex, temporary and so on. The most part of the received results is applicable for static assessment of separate parameters. But there are not enough works on dynamic modeling of these parameters and practically at all there are no publications on creation of complex dynamic models of biological systems. The most significant results in this area are received during the multiple parameter modeling directed to a research of a functional condition of an organism. This approach is in detail described in [3].

In [3] physiological systems are described on the base of the results of researches and scientific representations of the academician P.K. Anokhin [1]. Results of system researches are based on the estimation of average criteria functions (CF) given in [5] and functionals [4].

Criterial functions are calculated on basis of results of separate parameters measurements, that characterize the state of the investigated system. For the entire selection of the biosystem, a correlation matrix is constructed. It can be done using the branches and boundaries procedure with the choice of the optimal subset of characteristics and evaluation of the criterial function for each patient [5]. The method is based on assessment of a monotonous function — CF from any biological set A. The algorithm is constructed on calculation of the maximum CF on the basis of a certain quadratic form and on search of the biggest set of *n* of variables maximizing CF for all subset containing *m* features. CF is calculated through a quadratic form: $C(A_m) = (X_m^T)S_m^{-1}(X_m)$, where A_m — set *m* of variables, X_m — a vector of variables (a set of bioparameters — the functional system of the specific patient) and S_m — symmetric positively certain correlation matrix of the $m*m$ size; the symbol of X_m^T means transposing operation of a vector, S_m^{-1} — operation of calculation of an inverse matrix.

Calculation of functionals of biosystems is based on search of decomposition $R = (R_1, R_2, \ldots, R_M)$ sets of objects (parameters of acid-base state (ABS)) on not crossed classes that are sets of the functional subsystem of parameters of ABS: $R_1, R_2, \ldots, R_M$ ($M = 1$ or $M > 1$), which gives local maximum to F - the sum of "internal" correlation links minus some threshold value of correlations characterizing their importance: , where a — a threshold of importance of links (at $a_{ij} > a$ the link is stronger between objects *i* and *j*, at $a_{ij} < a$ — the link is insignificant), a_{ij} — is an indicator of linkage between *i-th* and *j-th* objects ($a_{ij} = a_{ji}$, a_{ii} — aren't investigated and aren't considered), expression $i, j \in R_S$ means that a_{ij} is an element belonging to a R_S set [4].

The considered approach allows take into account important features of biological systems. The first feature is that the analysis and assessment of a condition of systems is carried out taking into account change of values of the parameters in comparison with values which were earlier observed. The second feature consists in need of assessment of coherence of changes of various parameters of a system among themselves in the context of the general condition of an organism. In our case observed changes reflect mismatch in functioning of a system, then dynamics of such mismatch can be analyzed.

Successful practical application of this approach requires existence of the relevant decisions allowing provide its realization with the help of MIS. The details of this approach is discussed in the next sections.

Processes of synthesis of integrated models of system dynamics

Synthesis of integrated models on the basis of methods of the system analysis assumes preliminary preparation of data. The groups of patients having the general main diagnosis and also similar accompanying diagnoses are taken into account. Besides, in the process of forming groups other influencing factors are considered, such as age and sex of the patient.

In the process of synthesis all measured parameters relating to the studied system are considered. Their number, as a rule, makes many dozens. In the table 1 the example of the parameters measured in the analysis of ABS of patients is given.

Reduction of number of parameters with use of statistical methods of assessment of informational content of parameters is not recommended as it can lead to loss of information about internal dependences of elements of systems. It is because that at use of a considerable part of methods the correlating parameters are excluded from consideration.

For control of a condition of patients all or a part of parameters are measured several times through some intervals of time. Time

Parameter name	Description of the parameter	Parameter name	Description of the parameter
pH	Acidity	Ca++	Calcium ion concentration
pO2	Oxygen partial pressure	Cl-	Chlorine Ion concentration
pCO2	Carbon dioxide partial pressure	Glu	Glucose concentration
ABE	Excess base	Lac	Lactate content
SBE	Lack of reason	p50	Hemoglobin affinity for oxygen
cHCO3	Plasma bicarbonate	mOsm	Blood osmolarity
cHCO3-st	Bicarbonate (alkali)	pH(T)	Acidity corrected for temperature
sO2	Oxygen boost		
ctHb	Reference hemoglobin level	pO2(T)	Partial oxygen pressure adjusted for temperature
Htc	Hematocrit		
K+	Potassium ion concentration	pCO2(T)	Carbon dioxide partial pressure adjusted for temperature
Na+	Sodium ion concentration		

Table 1: Parameters of ABS.

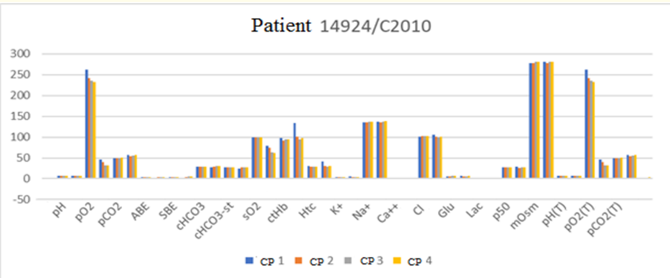
points in which measurements are taken are considered as control points. Results of measurements, as a rule, have many missed values. Methods of recovery of data must be applied to their filling. Rather good results can be received with the help of the KNN data filtering (K-Nearest Neighbors). Examples of the restored parameters measured in several points of control (CP) for patients of various groups are shown in figure 1.

Using prepared data criteria functions or functionals are calculated. Calculations are carried out according to the data obtained in each control point. On the values calculated in control points the integrated curves bearing information on dynamics of change of a condition of ABS are restored. Statistical processing and comparison of CF is realized with the help of nonparametric criteria, in particular, by Mann-Whitney and Kruskala-Wallice's standard nonparametric criteria [2].

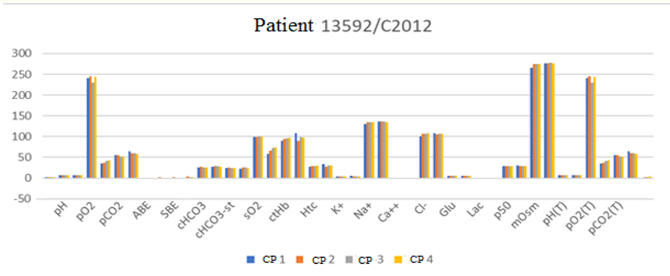
Dynamic model of ABS

During the considered process of synthesis the dynamic model of ABS of the patient is to be constructed. The general structure of a dynamic model and schedules of an integrated curve of ABS corresponding to each control point are shown in figure 2.

The model describes changes of ABS of patients in dynamics. Six control points of assessment of a condition of patients fall on the considered period (CP No. 1 - No. 6). By data in each control point the private model is constructed. Private models that are linked with each other form a dynamic model. The model shown in the fig. 2 includes six private models.



a)



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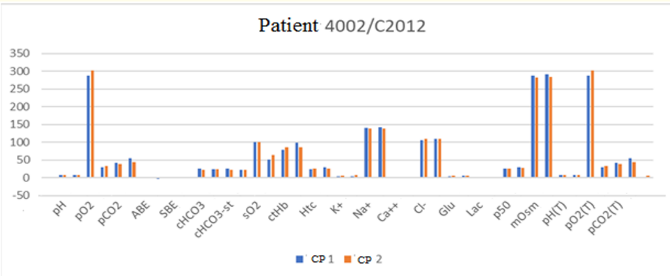

c)

Figure 1: Parameters ABS for patients of various groups.

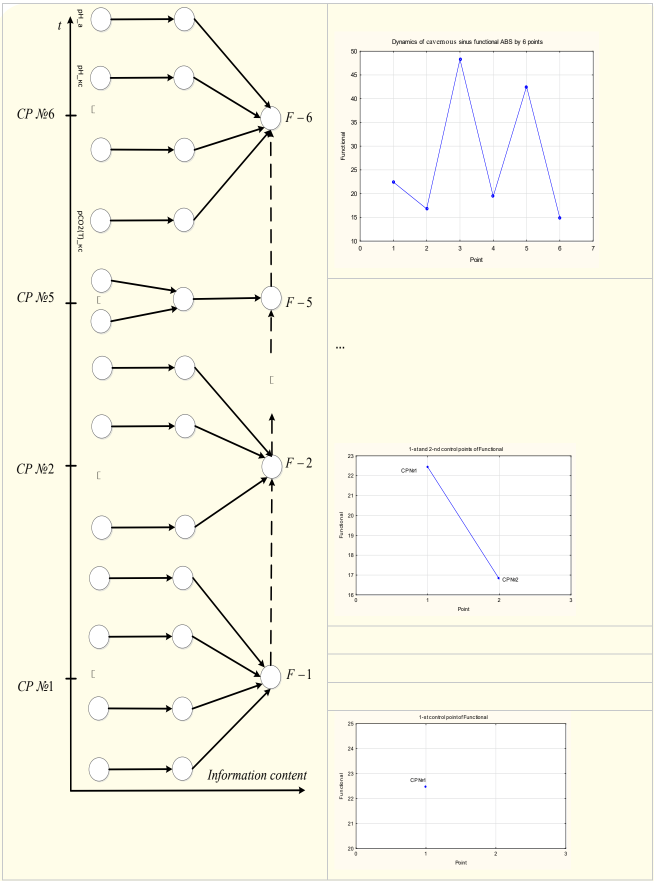

Figure 2: Dynamic model of ABS.

Private models have multilevel structure. The lowest level of models is the level of initial parameters (pH_a - pCO2(T)). The following level is the level of the restored data. At the top level results of calculation of integrated indicators or functionals are placed (F-1 – F-6). An integrated curve is the curve constructed on F-1 points – F-6.

Method of the analysis of dynamics of ABS

The analysis of dynamics of ABS on the basis of the calculated CF values provides execution of a number of steps for realization of the suggested method. Let's explain this method on the example of the analysis of conditions of three groups of patients on six control points.

Method includes

Calculation of average indicators of CF of ABS.

Calculation of average indicators of CF of ABS on all control points. As indicators an average, a median, a minimum, a maximum, a lower quartile, a top quartile, a standard deviation, a standard error are calculated. Result are presented in the table 2.

All 3 groups	Parameters
Group 1	< values are calculated for all control pints of the group 1>
Group 2	< values are calculated for all control pints of the group 2>
Group 3	< values are calculated for all control pints of the group 3>

Table 2: Calculation of average indicators of CF of ABS on all control points.

Calculation of average indicators of CF of ABS for each control point separately. For each group table 3 is filled out.

№ of point	Parameters
Point 1	< values are calculated on the basis of data of one group>
Point 2	< values are calculated on the basis of data of one group>
Point 3	< values are calculated on the basis of data of one group>
Point 4	< values are calculated on the basis of data of one group>
Point 5	< values are calculated on the basis of data of one group>
Point 6	< values are calculated on the basis of data of one group>

Table 3: Calculation of average indicators of CF of ABS for each control point.

Research of average indicators

A research of ratios of indicators in various groups on all control points. Paired comparison of the ABS CF values is calculated according to 1.1. At assessment of ratios comparison of indicators is carried out by Mann-Whithney's criterion. Results of comparison are presented in the table 4.

An analysis of ratios of indicators in adjacent control points on all groups. Paired comparison in the points of research CF ABS calculated for all groups is carried out. Results are shown in table 5.

Research of average indicators of each group of patients. Ratios of indicators in adjacent control points are investigated. In control points paired comparison of CF of ABS is carried out. The structure of the table is similar to structure of table 5, but values are calculated for one group.

Couple of group sunder investigation		Parameters of ratio
Group 1	Group 2	
<value>	<value>	< values are calculated for all control points>
Group 1	Group 3	
<value>	<value>	< values are calculated for all control points>
Group 2	Group 3	
<value>	<value>	< values are calculated for all control points>

Table 4: Ratios of indicators in various groups on all control points.

Pair of points under investigation		Parameters of ratio
Point 1	Point 2	
<value>	<value>	< values are calculated for all groups>
Point 1	Point 3	
<value>	<value>	<values are calculated for all groups>
Point 1	Point 4	
<value>	<value>	< values are calculated for all groups>
Point 1	Point 5	
<value>	<value>	< values are calculated for all groups>
Point 1	Point 6	
<value>	<value>	< values are calculated for all groups>

Table 5: Ratios of indicators in adjacent control points on all groups.

A research of average indicators between groups of patients. Ratios of indicators in control points between groups are investigated. For each control point paired comparison of indicators of CF of the ABS calculated for various groups is carried out. The example of the received results is given in the table 6.

Pair of points under investigation		Parameters of ratio
Point 3 1-st group	Point 3 2-nd group	
<value>	<value>	< values are calculated for specific group>

Table 6: Average indicators between groups of patients.

The analysis of dynamics of ABS on the basis of calculation of functionals is offered to be carried out by the technique given below. According to it three indicators – functionality, a threshold of importance of links and quantity of classes of decomposition are calculated and estimated:

1. Calculation of indicators of functionals, thresholds of importance of links and classes of decompositions of ABS in all 3 groups.
2. Calculation of indicators of functionals, thresholds of importance of links and classes of decompositions of ABS in the first, second and third groups separately.
3. Research of behavior of indicators of functionals, thresholds of importance of links and change of number of classes of decompositions.
    - Analysis of behavior of indicators of functionals.
    - Analysis of behavior of an indicator of a threshold of importance of links.
    - Joint analysis of indicators of functionals, threshold of importance of links and change of number of classes of decompositions.
    - Identification of critical periods in a state of a system.

The considered approach can be applied both separately or together. Results of researches of dynamics of ABS are given below. In the first part the analysis is carried out on the basis of calculation of CF, and in the second – on the basis of calculation of functionals.

Experimental research

The dynamics of the ABS in cavernous sinus (CS) was studied for 391 patients with cardiac surgical pathology during the postoperative period in the operating room and in the cardio-resuscitation unit at 6 points. 21 parameters of the ABS were considered. The parameters are listed in Table 1.

Analyses of acid-base state in cavernous sinus of patients with cardiac surgical pathology on the base of criteria functions calculation

The results of calculation of the average statistical indicators of criteria functions of ABS in a cavernous sinus of 1, 2 and 3 groups of patients are presented in table 7 (format of table 2). Indicators for each of the groups separately are given in tables 8-10 (format of table 3).

	Sample size	Average	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation.	Standard error
All 3 groups	391	4,633364	4,692077	2,842360	5,979059	4,164943	5,110298	0,632705	0,031997
Group 1	162	4,564909	4,562087	2,842360	5,979059	4,123383	5,038392	0,627679	0,049315
Group 2	178	4,681697	4,825765	2,907487	5,749387	4,230775	5,137846	0,632870	0,047436
Group 3	51	4,682120	4,699149	3,319812	5,764247	4,159608	5,211254	0,640360	0,089668

Table 7: Average indicators of CF of ABS in a cavernous sinus of 1, 2 and 3 groups on all points.

	Sample size	Average	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation	Standard error
Point 1	29	5,181532	5,334604	3,335973	5,979059	4,930786	5,581981	0,565361	0,104985
Point 2	29	4,570183	4,577556	3,055679	5,538977	4,332765	4,839415	0,494325	0,091794
Point 3	29	4,290401	4,360204	3,082799	5,563048	3,918768	4,731078	0,637255	0,118335
Point 4	29	4,398617	4,304438	2,842360	5,660760	4,025203	4,852020	0,614702	0,114147
Point 5	25	4,364845	4,257348	2,973403	5,508473	4,064906	4,714258	0,587974	0,117595
Point 6	21	4,552997	4,469162	4,030473	5,243985	4,354309	4,788655	0,344472	0,075170

Table 8: Average indicators of CF of ABS in a cavernous sinus in the 1st group on all points.

	Sample size	Average	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation	Standard error
Point 1	31	5,030134	5,039286	3,994927	5,749387	4,662242	5,444354	0,496898	0,089245
Point 2	31	4,649030	4,870252	3,262338	5,729507	4,063050	5,244133	0,701342	0,125965
Point 3	31	4,664468	4,785031	3,264373	5,613649	4,233283	5,097482	0,642957	0,115479
Point 4	31	4,617496	4,765347	3,304917	5,576111	4,051669	5,041625	0,578045	0,103820
Point 5	27	4,594439	4,825537	2,907487	5,542262	4,230315	5,031717	0,657172	0,126473
Point 6	27	4,499897	4,581729	3,443497	5,690856	3,982962	4,963708	0,621499	0,119607

Table 9: Average indicators of CF of ABS in a cavernous sinus in the 2nd group on all points.

	Sample size	Average	Median	Minimum	Maximum	Lower quartile	Upper quartile	Standard deviation	Standard error
Point 1	25	4,960760	5,119524	3,680534	5,764247	4,619946	5,464411	0,577811	0,115562
Point 2	2	4,009480	4,009480	3,319812	4,699149	3,319812	4,699149	0,975339	0,689669
Point 6	24	4,447923	4,460329	3,469589	5,407736	3,962353	4,935827	0,566329	0,115601

Table 10: Average indicators of CF of ABS in a cavernous sinus in the 3rd group on all points.

Below in figure 3 – 6 the corresponding schedules of a system indicator of ABS – criteria function are provided in average and for groups 1,2,3.

Results of comparison of CF of ABS in a cavernous sinus of the 1, 2 and 3 groups on all points: 1,2,3,4,5,6 by Mann-Whitney U Test criterion are given in table 11. Results of paired comparison in points of research of CF of ABS in a cavernous sinus of all groups on Mann-Whitney U Test criterion – in table 12.

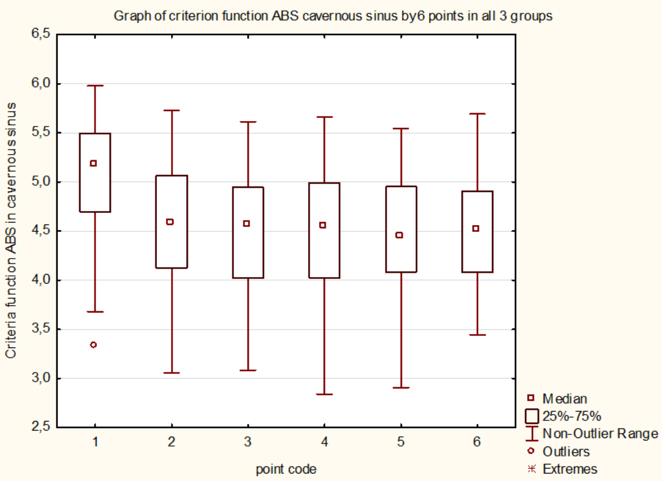

Figure 3: The average dynamics of CF of ABS in a cavernous sinus in three groups.

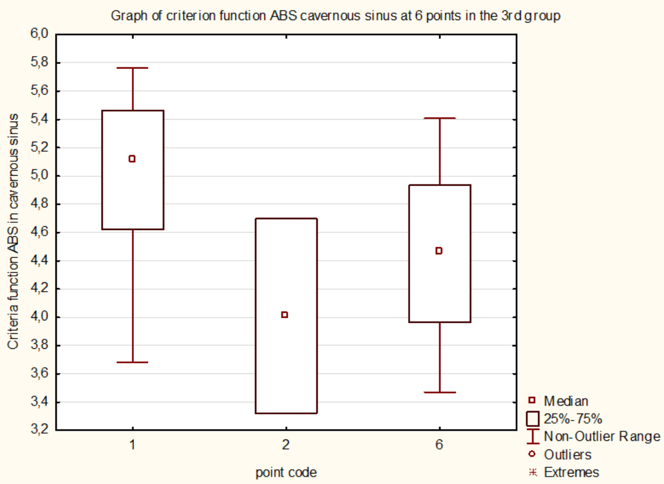

Figure 6: The average dynamics of CF of ABS in a cavernous sinus in the 3rd group.

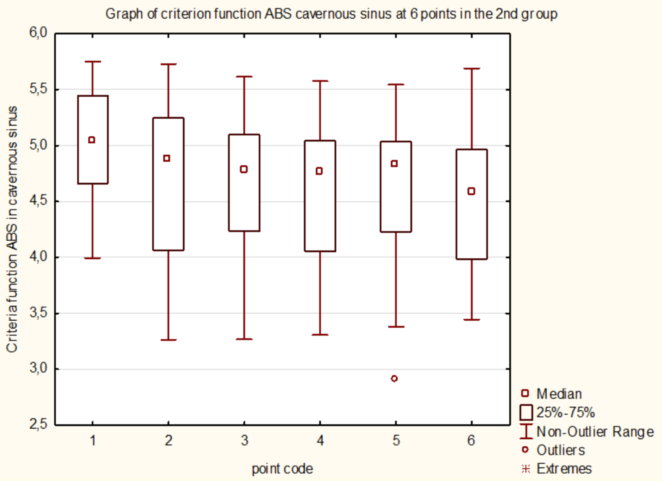

Figure 5: The average dynamics of CF of ABS in a cavernous sinus in the 2nd group.

Results in table 11 show significant difference of the CF average on group values of ABS between the 1st and 2nd groups.

Table 12 indicates paired difference of CF of ABS between the 1 point of the research from each of the 2, 3, 4, 5 and 6 points in all three groups. From this it follows that value of CF of ABS in the 1st point of a research significantly differ from the subsequent researched points.

In tables 13-15 paired comparison in points of research of CF ABS in a cavernous sinus in the 1st, 2nd and 3rd group separately are given.

Results of Table 13 show paired difference of CF of ABS between 1 point of the research from each of the 2, 3, 4, 5 and 6 points in the 1st group. Other paired comparisons in the 1st group haven't given significant differences.

Results of Table 14 show paired difference of CF of ABS between the 1 point of the research from each of the 2, 3, 4, 5 and 6 points in the 2nd group.

Other paired comparisons in the 2nd group haven't given significant differences.

Results of Table 15 show paired difference of CF of ABS between the 1 point of the research and the 6th point in the 3rd group. Other paired comparisons in the 3rd group haven't given significant differences.

Comparison on points between the 1st, 2nd and 3rd groups allow identify the following:

- In the 1st point paired comparisons haven't given significant differences;
- In the 2nd point paired comparisons haven't given significant differences;
- In the 3rd point paired comparisons have revealed significant differences between the 1st and 2nd groups.

Rank sum		U	Z	p-value	Sample size	
Group 1	Group 2				Group 1	Group 2
25793,00	32177,00	12590,00	-2,01885	0,043504	162	178
Group 1	Group 3				Group 1	Group 3
16887,00	5904,000	3684,000	-1,16322	0,244740	162	51
Group 2	Group 3				Group 2	Group 3
20496,00	5839,000	4513,000	0,061132	0,951254	178	51

Table 11: Comparison of CF of ABS in a cavernous sinus of 1, 2 and 3 groups on all points: 1,2,3,4,5,6 by Mann-Whitney U Test criterion.

Rank sum		U	Z	p-value	Sample size	
Point1	Point 2				Point 1	Point 2
7469,000	3409,000	1456,000	4,622576	0,000004	85	62
Point 1	Point 3				Point 1	Point 3
7486,000	3099,000	1269,000	5,140539	0,000000	85	60
Point 1	Point 4				Point 1	Point 4
7521,000	3064,000	1234,000	5,281046	0,000000	85	60
Point 1	Point 5				Point 1	Point 5
7013,000	2440,000	1062,000	5,089705	0,000000	85	52
Point 1	Point 6				Point 1	Point 6
8411,000	3992,000	1364,000	5,972885	0,000000	85	72

Table 12: Paired comparison in points of research of CF of ABS in a cavernous sinus of all groups on Mann-Whitney U Test criterion.

Rank sum		U	Z	p-value	Sample size	
Point 1	Point 2				Point 1	Point 2
1132,000	579,0000	144,0000	4,292158	0,000018	29	29
Point 1	Point 3				Point 1	Point 3
1161,000	550,0000	115,0000	4,743146	0,000002	29	29
Point 1	Point 4				Point 1	Point 4
1141,000	570,0000	135,0000	4,432120	0,000009	29	29
Point 1	Point 5				Point 1	Point 5
1051,000	434,0000	109,0000	4,388952	0,000011	29	25
Point 1	Point 6				Point 1	Point 6
957,0000	318,0000	87,00000	4,265369	0,000020	29	21

Table 13: Paired comparison in points of research of CF of ABS in a cavernous sinus in the 1st group on Mann-Whitney U Test criterion.

Rank sum		U	Z	p-value	Sample size	
Point 1	Point 2	338,0000	1,999157	0,045592	Point 1	Point 2
1119,000	834,0000				31	31
Point 1	Point 3	325,0000	2,182179	0,029097	Point 1	Point 3
1132,000	821,0000				31	31
Point 1	Point 4	284,0000	2,759400	0,005791	Point 1	Point 4
1173,000	780,0000				31	31
Point 1	Point 5	254,0000	2,556500	0,010574	Point 1	Point 5
1079,000	632,0000				31	27
Point 1	Point 6	213,0000	3,195625	0,001395	Point 1	Point 6
1120,000	591,0000				31	27

Table 14: Paired comparison in points of research of CF ABS in a cavernous sinus in the 2nd group on Mann-Whitney U Test criterion.

Rank sum		U	Z	p-value	Sample size	
Point 1	Point 6				Point 1	Point 6
761,0000	464,0000	164,0000	2,710000	0,006729	25	24

Table 15: Paired comparison in points of research of CF of ABS in a cavernous sinus in the 3rd group on Mann-Whitney U Test criterion.

The differences are presented in table 16;

- In the 4th point paired comparisons haven't given significant differences;
- In the 5th point paired comparisons haven't given significant differences;
- In the 6th point paired comparisons haven't given significant differences.

In total the results of the research allow make the following conclusions about the dynamic of ABS of patients in CS:

1. CF average for the groups values of ABS between the 1st and 2nd groups differ significantly.
2. Pairwise significantly differ average values of CF of ABS of CS between the 1 point of the research from each of the 2, 3, 4, 5 and 6 points in average on points of all three groups.
3. The paired difference of CF of ABS in CS between the 1 point of the research from each of the 2, 3, 4, 5 and 6 points in the 1st group is revealed.
4. The paired difference of CF of ABS in CS between the 1 point of the research from each of the 2, 3, 4, 5 and 6 points in the 2nd group is revealed.
5. Pairwise differ CF of ABS in CS between the 1 point of the research and the 6th point in the 3rd group.
6. In the 3rd points of research CF of ABS in a cavernous sinus between the 1st and 2nd groups significantly differ.

Analyses of acid-base state in a cavernous sinus of patients with cardiac surgical pathology on the base of functionals

The ABS in cavernous sinus of patients was also analyzed on the base of functionals calculation. Figure 7 and tables 17 and 18 describe dynamics of systemic and correlation links and corresponding changes of cooperative correlation relationship between a set of indicators of the ABS during the research of the joint three groups of patients. It is visually seen that the threshold of importance of links shows significant decrease from the 1st (0.622) to the 4th (0.350) point and, starting with the 5th increases to value of the 6th point (0.431). At the same time the quantity of classes of decomposition decreases from 9 in the 1st point to 2 in the 3rd researched point. The quantity of classes of decomposition and an indicator of a functional are almost in an antiphase. According to table 18 the 3rd point of the research can be estimated as the most "intense" moment in the system as at this time there is a join of the set of parameters of ABS in only 2 not crossed classes with rather small coefficient of correlation equal to 0.380 that is quite close to the minimum of the threshold 0.350 in the 2nd point.

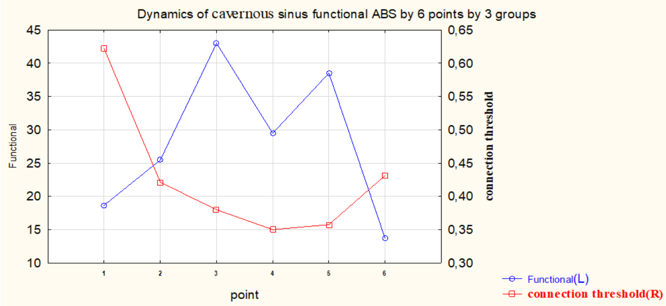

Figure 7: Dynamics of functionals and thresholds of importance of links of parameters of ABS in a cavernous sinus in all 3 groups.

The indicator of a functional respectively increases from the 1st point (18.667) to the 3rd and reaches here a maximum (43.011) then falls to the minimum in the 6th point (13.694). And this moment from the 5th to the 6th points can be considered according to [7] as the most critical period of the research since here the relation of the subsequent value of the functional to previous is minimal. Therefore the period from the 5th to the 6th point demonstrates critical changes in the system as here the considerable differences in indicators of the functional from 38.515 to 13.694, almost by 3 times with increase in decomposition of classes twice from the 4 to 8 times are observed.

Results presented in the figure 8 and tables 19 and 20 describe dynamics of systemic and correlation links and corresponding changes of cooperative correlation relationship between a set of indicators of an ABS during the research in the 1st group of patients.

Rank sum		U	Z	p-value	Sample size	
Point 3 1-st group	Point 3 2-nd group				Point 3 1-st group	Point 3 2-nd group
724,0000	1106,000	289,0000	-2,36682	0,017942	29	31

Table 16: Paired comparison in the 3rd points of research of CF of ABS in a cavernous sinus between the 1st and 2nd groups on Mann-Whitney U Test criterion.

Investigation point	Functional	Connection threshold	Quantity of classes
1	18,667	0,622	9
2	25,475	0,421	8
3	43,011	0,380	2
4	29,492	0,350	5
5	38,515	0,358	4
6	13,694	0,431	8

Table 17: Indicators of functionals, thresholds of importance of links and quantity of classes of decompositions of ABS in a cavernous sinus in all 3 groups.

It is visually shown that the threshold of importance of links shows essential stability during the period from the 1st to the 5th point within sizes 0.45 – 0.49. However to the 6th point it sharply increases up to size of 0.654.

At the same time the quantity of classes of decomposition increases from 5-7 classes from the 1st to the 5th point up to 10 in the 6th point of the research. According to the results in table 19 transition from the 5th to the 6th point of the research can be estimated as most "intense" of the moments in the system as at this time there is "disintegration" of the set of parameters of ABS on 10 not crossed classes with sharp increase in a threshold of importance of links by 1.4 times from size 0.462 to 0.654. Thus, at the end of the research in the 1 group to the 6th point the system was "scattered" - the quantity of classes of decomposition increased to 10, the threshold of importance of links grew to 0.654, and the functional in turn fell to minimum value - 21.355 from 39.753, i.e. almost twice (1.86). According to [7] here too we have "the critical period" as during the period between the 5th and 6th points the relation of the subsequent value of the functional to previous is minimum.

	Point_1	Point_2	Point_3	Point_4	Point_5	Point_6
Var_Class_1	pH(T) Ca^{++} Htc ctHb pH	pCO_2(T) mOsm p50 Na+ $cHCO_3$-st cHCO3 SBE ABE	pCO_2(T) pH(T) p50 Htc ctHb pCO2 pH	pH(T) p50 Glu Ca^{++} Na^+ ctHb sO_2 $cHCO_3$-st cHC	pO_2(T) pH(T) mOsm Glu Cl- Na^+ sO_2 $cHCO_3$-st c	pH(T) p50 Cl^- sO_2 pH
Var_Class_2	pO_2(T) sO_2 pO_2	pO_2(T) sO_2 pO_2	pO_2(T) mOsm Lac Glu Cl- Ca^{++} Na^+ K^+ sO_2 cHCO	pO_2(T) Cl- pO_2	pCO_2(T) p50 Lac Htc ctHb pCO_2	pO2(T) Glu $cHCO_3$ pO_2
Var_Class_3	pCO_2(T) p50 pCO_2	Htc ctHb		pCO2(T) pCO_2	K+	pCO2(T) pCO_2
Var_Class_4	$cHCO_3$-st $cHCO_3$ SBE ABE	Lac K^+		Htc	Ca++	Ca^{++} $cHCO_3$-st SBE ABE
Var_Class_5	K^+	Ca^{++}		mOsm Lac K+		Htc ctHb
Var_Class_6	mOsm Na^+	Cl^-				K^+
Var_Class_7	Cl^-	Glu				mOsm Na^+
Var_Class_8	Glu	pH(T)				Lac
Var_Class_9	Lac					

Table 18: Decompositions into not crossed classes of parameters of ABS in a cavernous sinus in all 3 groups.

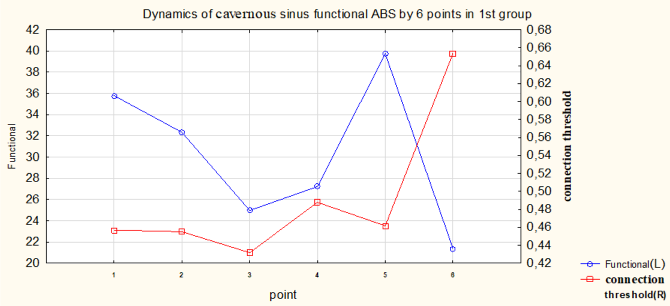

Figure 8: Dynamics of functionals and thresholds of importance of links of parameters of ABS in a cavernous sinus in the 1st group.

Investigation point	Functional	connection threshold	Quantity of classes
1	35,794	0,457	5
2	32,341	0,455	6
3	24,975	0,432	5
4	27,221	0,488	7
5	39,753	0,462	5
6	21,355	0,654	10

Table 19: Indicators of functionals, thresholds of importance of links and quantity of classes of decompositions of ABS in a cavernous sinus in the 1st group.

	Point_1	Point_2	Point_3	Point_4	Point_5	Point_6
Var_Class_1	pH(T) $cHCO_3$-st SBE ABE pH	pCO_2(T) pH(T) mOsm p50 Ca++ Na+ K+ Htc ctHb	pO_2(T) pH(T) Lac Cl- Htc ctHb sO_2 pO_2 pH	pH(T) Glu Htc ctHb $cHCO_3$-st $cHCO_3$ SBE ABE pH	pCO_2(T) pH(T) p50 Lac Cl- K+ Htc ctHb $cHCO_3$-	pH(T) $cHCO_3$-st $cHCO_3$ SBE ABE pH
Var_Class_2	pO_2(T) sO_2 pO_2	pO_2(T) sO_2 pO_2	pCO_2(T) p50 pCO_2	pO_2(T) sO_2 pO_2	pO_2(T) sO_2 pO_2	pO_2(T) sO2 pO2
Var_Class_3	pCO_2(T) mOsm p50 Lac Glu Cl^- Ca^{++} Na^+ Htc ct	$cHCO_3$-st $cHCO_3$ SBE ABE	K+ $cHCO_3$-st $cHCO_3$ SBE ABE	pCO2(T) p50 Lac pC_02	mOsm Na+	pCO_2(T) Cl^- pCO_2
Var_Class_4	$cHCO_3$	Cl^-	mOsm Na^+	K^+	Ca^{++}	Htc ctHb
Var_Class_5	K^+	Glu	Glu Ca^{++}	mOsm Na^+	Glu	K^+
Var_Class_6		Lac		Ca^{++}		mOsm Na^+
Var_Class_7				Cl^-		Ca^{++}
Var_Class_8						Glu
Var_Class_9						Lac
Var_Class_10						p50

Table 20: Decompositions into not crossed classes aof parameters of ABS in a cavernous sinus in the 1st group.

Results presented in the figure 9 and tables 21 and 22 describe dynamics of systemic and correlation links and corresponding changes of cooperative correlation relationship between a set of indicators of an acid-base state during the research in the 2nd group of patients.

It is evident that the threshold of importance of correlations in the 2nd group shows essential instability in comparison with the 1st group during the entire period of the research from the 1st to the 6th point within sizes 0.316 – 0.735.

At the same time the quantity of classes of decomposition also varies from 6-12 in the 1st and 2nd points to 4-11 in the 5th and 6th points of the research.

Investigation point	Functional	Connection threshold	Quantity of classes
1	22,438	0,316	6
2	16,794	0,718	12
3	48,309	0,439	5
4	19,426	0,522	8
5	42,570	0,398	4
6	14,884	0,735	11

Table 21: Indicators of functionals, thresholds of importance of links and quantity of classes of decompositions of ABS in a cavernous sinus in the 2nd group.

	Point_1	Point_2	Point_3	Point_4	Point_5	Point_6
Var_Class_1	pH(T) Lac Ca^{++} K^+ Htc sO_2 $cHCO_3$-st $cHCO_3$ SBE	$cHCO_3$-st $cHCO_3$ SBE ABE pH	pO_2(T) pH(T) mOsm p50 Ca^{++} Na^+ K^+ sO_2 $cHCO_3$-	pH(T) Ca^{++} pH	pO2(T) pH(T) Glu Na^+ K^+ ctHb sO_2 $cHCO_3$-st cH	pH(T) pH
Var_Class_2	pO_2(T) pCO_2 pO_2	pO_2(T) sO_2 pO_2	pCO_2(T) pCO_2	pO_2(T) sO_2 pO_2	pCO_2(T) p50 Lac Ca++ Htc pCO_2	pO_2(T) sO_2 pO_2
Var_Class_3	pCO_2(T) p50 ctHb	pCO_2(T) pCO_2	Htc ctHb	pCO_2(T) pCO_2	Cl-	pCO_2(T) p50 pCO_2
Var_Class_4	mOsm Na+	Htc ctHb	Cl^-	mOsm Lac Glu Na^+ cHCO3-st cHCO3 SBE ABE	mOsm	$cHCO_3$-st $cHCO_3$ SBE ABE
Var_Class_5	Cl^-	K^+	Lac Glu	Htc ctHb		Htc ctHb
Var_Class_6	Glu	mOsm Na^+		K^+		K^+
Var_Class_7		Ca^{++}		Cl^-		mOsm Na^+
Var_Class_8		Cl^-		p50		Ca^{++}
Var_Class_9		Glu				Cl^-
Var_Class_10		Lac				Glu
Var_Class_11		p50				Lac
Var_Class_12		pH(T)				

Table 22: Decompositions into not crossed classes of parameters of ABS in a cavernous sinus in the 2nd group.

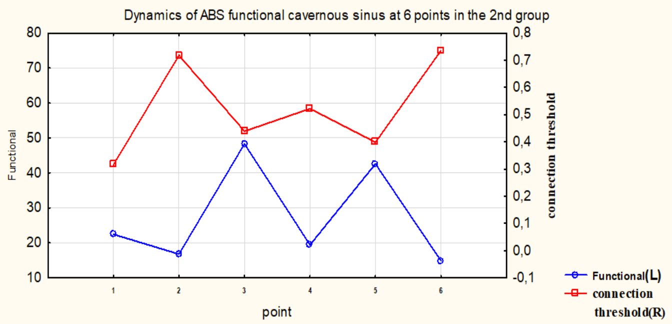

Figure 9: Dynamics of functionals and thresholds of importance of links of parameters of ABS in a cavernous sinus in the 2nd group.

According to results presented in table 21, transition from the 5th to the 6th point of the research can be estimated as well as in the 1st group as most "intense" of the moments in the system as at this time there is "disintegration" of the set of parameters of ABS on 11 not crossed classes with sharp increase in the threshold of importance of links by 1.85 times from size 0.398 to 0.735. Thus, at the end of the research in the 2nd group to the 6th point the system is "scattered" - the quantity of classes of decomposition increased to 11, the threshold of importance of links grew up to 0.735, and the functional in turn fell to minimum value – 14.884 from 42.57, i.e. almost by 3 times (2.86). According to [7] here too we have "the critical period" as during the period between the 5th and 6th points the relation of the subsequent value of the functional to previous is minimum. At the same time it should be noted that variations of sizes of both thresholds of importance of links and values of functionals in the 2nd group are much higher, than in the first group - almost twice (1.86) for functionals and 1.4 times for thresholds against respectively 2.86 and 1.85 for the 2nd group (Figure 10 and 11).

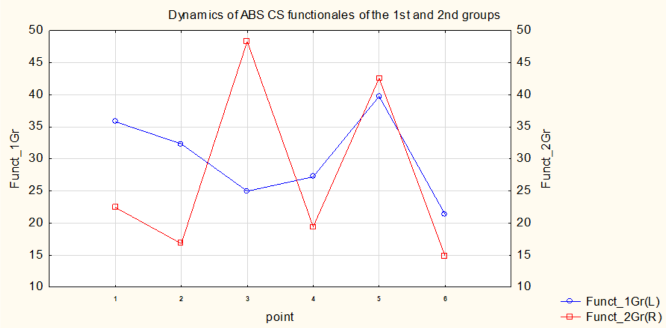

Figure 10: Dynamics of functionals of ABS in a cavernous sinus in the 1st and 2nd groups.

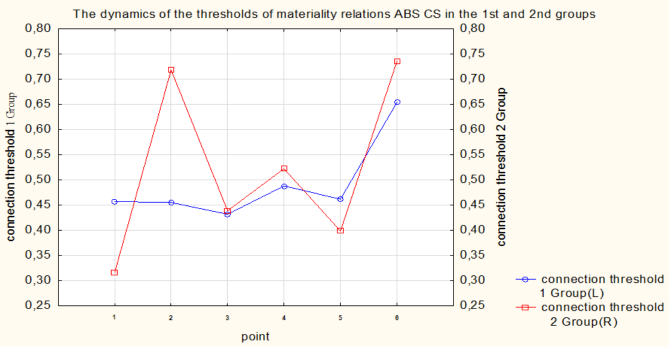

Figure 11: Dynamics of thresholds of importance of links of parameters of ABS in a cavernous sinus in the 1st and 2nd groups.

Research in the 3rd group is presented by 2 points – the 1st and 6th and it is described in figure 12 and tables 23 and 24. In this group the functional decreases from the 1st to the 6th point by 1.68 times at increase of a threshold of links by 1.43 times, and the number of classes of decomposition of parameters of ABS increases twice, that is the system will be disorganized in the 6th point that is visually shown in table 24 and figure 12.

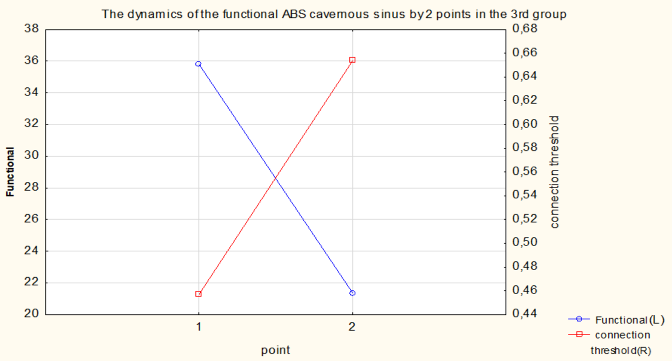

Figure 12: Dynamics of functionals and thresholds of importance of links of parameters of ABS in a cavernous sinus in the 3rd group.

Investigation point	Functional	Connection threshold	Quantity of classes
1	35,794	0,457	5
6	21,355	0,654	10

Table 23: Indicators of functionals, thresholds of importance of links and quantity of classes of decompositions of ABS in a cavernous sinus in the 3rd group.

	Point_1	Point_6
Var_Class_1	pH(T) $cHCO_3$-st SBE ABE pH	pH(T) $cHCO_3$-st $cHCO_3$ SBE ABE pH
Var_Class_2	pO_2(T) sO_2 pO_2	pO_2(T) sO_2 pO_2
Var_Class_3	pCO_2(T) mOsm p50 Lac Glu Cl- Ca^{++} Na^+ Htc ct	pCO_2(T) Cl- pCO_2
Var_Class_4	$cHCO_3$	Htc ctHb
Var_Class_5	K+	K^+
Var_Class_6		mOsm Na^+
Var_Class_7		Ca^{++}
Var_Class_8		Glu
Var_Class_9		Lac
Var_Class_10		p50

Table 24: Decompositions into not crossed classes of parameters of ABS in a cavernous sinus in the 2nd group.

In total the results of the research based on the calculation of functionals allow make the following conclusions about the dynamics of ABS in a cavernous sinus of patients with cardiac surgical pathology.

The maximum shifts in the system of parameters of ABS in a cavernous sinus of the 1st group of patients take place during the period between the 5th and 6th points of the research.

The maximum shifts in the system of parameters of ABS in a cavernous sinus of the 2nd group of patients take place also during the period between the 5th and 6th points of the research, but the variation of sizes of both the thresholds of importance of links and the values of functional is much higher in the 2nd group, than in the first group. In other words, the 2nd group has more unstable dynamics of parameters of ABS.

The 3rd group of patients has relatively small variations of the researched parameters.

Conclusion

The results of the research showed the effectiveness of the synthesis of integrated models for analysis of the ABS of the patients. The use of integral models made it possible to move from the description of the ABS, presented in the form of the results of measurements of 21 parameters of ABS of patients in a cavernous sinus, to a significantly more capacious representation of the integral curves without loss of information.

The proposed structured description of the synthesis process and the dynamic model of the ABS make it possible to put them into practice by means of modern information systems. In the formed processes, the use of complex specialized apparatus required for system analysis is considered as one of the necessary steps. The processes of synthesis of dynamic models based on the calculation of criteria functions and functionals are shown. The first model allows identify the distinctive features of ABS for various groups of patients and features of changes in conditions in the postoperative period. The second model is to achieve a deeper understanding of the acid-base state of the observed patients, to identify critical periods in their state.

The scope of the proposed solution is not limited to the analysis of the acid-base state of the organisms. If there is a sufficient number of measurement results of the system parameters, other complex systems can be analyzed and an assessment of the consistency of their functioning can be obtained.

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